

Pioneer Venus 1978 Mission Support

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Significant aspects of the Orbiter portion of the Pioneer Venus 1978 Mission are described.

I. Introduction

The Pioneer Venus 1978 Project will consist of two missions: an Orbiter Mission and a Multiprobe Mission. The Multiprobe Mission has been described in several previous *Deep Space Network Progress Report* articles; see in particular Refs. 1 and 2. This article will concentrate on the Orbiter Mission.

The Orbiter Mission will launch in late May or early June of 1978, using a Type II trajectory, while the Multiprobe Mission will be launched in August 1978, using a Type I trajectory. Both missions will arrive at Venus in early December 1978, the Orbiter arriving a few days before the Multiprobe. Both missions will utilize an Atlas SLV-IIID Centaur D-1AR launch vehicle, with approximately a 160-km altitude parking orbit. The Orbiter will be designed for a minimum lifetime of 243 Earth days in Venusian orbit which corresponds to one Venusian day. The spacecraft will be constructed by the Hughes Aircraft Company under contract to Ames Research Center, which has Project management responsibilities.

II. Orbiter Spacecraft Characteristics

The Pioneer Venus 1978 Orbiter and Multiprobe spacecraft were designed to use as much common hardware as feasible in these distinctly different missions. A commonality on the order of 70% has been claimed. The Orbiter spacecraft is shown schematically in Fig. 1. The spacecraft is spin-stabilized with a mechanically despun antenna system. The spacecraft is 254 cm (100 in.) in diameter and will use spin rates between 5 and 30 rev/min during the life of the mission. Total mass of the spacecraft is 576 kg (1270 lb) accommodating approximately 45 kg (100 lb) of scientific instruments. There are 12 on-board experiments, two of which are common to the bus spacecraft of the multiprobe mission. Located on the spin axis, below the equipment shelf, is a solid orbit insertion motor. A monopropellant hydrazine system provides propulsion for all velocity correction maneuvers, attitude, and spin control, using four radial and three axial thrusters. The outer surface of the cylindrical portion of the spacecraft is covered with a solar array to provide spacecraft power. Located on the spin axis above the

equipment shelf is a despun antenna mask accommodating a high-gain parabola used for both S- and X-band, a sleeve dipole antenna serving as the medium-gain antenna to back up the parabola, and at the top a forward omniantenna. To complete the omniantenna pattern, an off-axis antenna is provided on the aft end of the spacecraft. The sleeve dipole antenna is linearly polarized, and all other antennas are right-hand circularly polarized. The high-gain antenna is 109 cm (43 in.) in diameter.

III. Science Payload

The Orbiter mission will carry a complement of 12 scientific instruments. The on-board instruments are listed in Table 1. In addition, there are six ground-based radio science experimenters who will utilize the telecommunications link from the spacecraft and ground-based equipment for their experiments, which are listed in Table 2.

The individual experiments listed in Tables 1 and 2 will be described in more detail in subsequent *Deep Space Network Progress Report* articles on the Pioneer Venus 1978 Mission.

IV. Mission Description

The Orbiter Mission will be launched between May 6 and June 4, 1978, using a Type II trajectory. The encounter window at Venus is between Dec. 4 and Dec. 12 1978. Preliminary mission sequence calls for separation from Centaur and initial spinup at launch plus 30 min and magnetometer boom deployment at launch plus 4 hours. Velocity corrections en route to Venus would occur at launch plus 5 days, launch plus 20 days, and at Venus Orbit Insertion (VOI) minus 20 days in the nominal mission. VOI would occur at approximately launch plus 200 days. The spin rate of the spacecraft would be 5 rev/min at Centaur separation, 15 rev/min during the cruise phase, 30 rev/min during the orbit insertion, and 5 rev/min during the orbital mission phase.

Figure 2 shows the Earth and Venus locations at the start and end of the 243 Earth-day primary mission. During that 243 days, Venus will have completed slightly more than one orbit around the Sun and one complete rotation on its axis. Although the final Venus orbit has not been selected, the following is typical for planning purposes: an orbital inclination that is 80 deg retrograde with an orbital period of 24 Earth hours. Peripasis altitude would be maintained between 150 and 260 km, and the

latitude of periapsis would vary between 15 deg and 32 deg north. This trajectory will result in the prime Earth occultations (those occurring at periapsis) occurring from Day 0 to Day 75 in orbit with a maximum duration of the occultation of 25 min. There will be two periods of solar occultation (or eclipse) from Day 25 to Day 120, with a maximum eclipse of 25 min, and again from Day 183 to Day 189 in orbit with a maximum duration of 3.8 h.

Maintaining the orbit with such a low periapsis altitude will require orbital adjustment maneuvers perhaps as often as once a week, but at least as often as once a month, during the primary orbital mission.

The Orbiter spacecraft includes a 1.048×10^6 -bit memory and a redundant 128-instruction command sequencer. The basic mission plan was to be able to operate on a 26-m Deep Space Station using a single pass each day centered on periapsis. During this station pass, the data from the apoapsis could be recalled from the spacecraft, the command sequence reloaded for the next 24 hours, the periapsis data taken at high rate into the spacecraft memory, and finally, the periapsis data played out of the memory to the station. As the mission design has progressed, the coverage requirements have grown considerably due to occultation requirements and expanding data rate requirements of some of the instruments. Table 1 contains a list of the currently estimated Pioneer Venus Orbiter DSN coverage requirements. The rather complex Fig. 3 (designed by J. Dyer of the Pioneer Project Office) is an attempt to portray these coverage requirements pictorially. The diagonal line in Fig. 2 extending from 16 GMT on Day 0 represents a tentative selection by the Project of a time for periapsis passage. This was selected to have the periapsis passage during the mutual Goldstone-Australia Deep Space Station view period to try and help minimize the coverage conflict between Pioneer Venus and the Mariner Jupiter-Saturn (MJS) missions which will be flying during the same time period, which includes the two Jupiter encounters. The 2-hour band extending out to Day 120, becoming 3 hours out to the end-of-mission, is the basic 26-m coverage requirement in order to perform the daily data recovery from the spacecraft memory and reloading of the command sequencer. The increase in number of hours around Day 120 is necessary due to the decreasing bit rate. Remembering Fig. 2, the range to the spacecraft while in orbit around Venus continually increases during the primary mission, which ends just before the first superior conjunction. Figure 4 translates this range increase to the bit rate as a function of days in orbit for both a DSN 26-m and a 64-m antenna, assuming the spacecraft is using the high-gain antenna and is in the high-power mode.

The prime occultations occur for the first 70 to 80 days of orbit and require 64-m coverage of approximately three hours centered on periapsis because of signal level requirements and the requirement for X-band reception. This coverage requirement is shown as the cross-hatch section in Fig. 3 along the diagonal out to Day 80. Recall that many orbit adjustment maneuvers will be required because of the low periapsis altitude, and therefore a minimum coverage requirement for radio metric data purposes for navigation has been established as a 26-m, 24-h pass at least two days out of every six, although continuous 26-m coverage is preferred. There will also be approximately 15 days of apoapsis occultations between Day 150 and Day 165, which, because of their duration, will require on the order of six hours of 64-m coverage. This is shown in Fig. 3 as the cross-hatched, irregular polygon centered on Day 160. An on-board instrument, whose data rate requirements have added to the coverage requirements, is the cloud photopolarimeter (CPP). This instrument has two modes: a polarimetry mode, requiring medium data rates; and an imaging mode requiring higher data rates. Neither of these modes can be accommodated by using the megabit memory and are therefore required to be received in real-time. The polarimetry requirement requires 18 hours per day of 26-m coverage in two approximately 10-day blocks during the mission. Table 3 lists typical days for the polarimetry observation. The imaging portion of the experiment requires two 10-day blocks of continuous 64-m coverage, which is pictured as the two vertical bands in Fig. 3 at about 100 and 120 days. In addition, 8 hours per day of 64-m coverage for apoapsis photography is required for 30 days spread between the 40th and 110th day in orbit. The most recently identified additional coverage requirement will be for 64-m coverage for a radar imaging experiment; however, the details of this requirement have not been determined.

Extensive negotiations between the Pioneer Venus Project and the MJS Project are in process in order to try to accommodate the coverage requirements of these two missions as well as Pioneer 10 and 11 during the orbital phase of the Pioneer Venus Mission. The preliminary work so far accomplished in the negotiations between these two projects indicates that, in general, the Pioneer Venus and MJS coverage requirements can probably be met, but the minimum coverage that is acceptable to Pioneer 10 and 11 will be extremely difficult to provide.

V. Telecommunications

The Pioneer Venus Orbiter spacecraft will be transmitting continuous telemetry using PCM/PSK/PM (biphase) modulation of the S-band carrier. The subcarrier frequency

will be 32.768 kHz with a modulation index of either 37.2 or 67.6 deg, which is selectable by ground command independent of bit rate. The spacecraft can transmit at the following rates: 8, 16, 64, 128, 170-2/3, 256, 341-1/3, 512, 682-2/3, 1024, and 2048 bits/s. 4096 bits/s might also be possible in the early phase of the mission, although it is not yet known whether the DSN can support that data rate with sequential decoding. The normal operating mode of the spacecraft will be long-constraint-length convolutional coding to be sequentially decoded. All formats are 512 bits in length, using 64 8-bit words and incorporating a 24-bit sync word (76142511₈). Since the constraint length is 32, the encoder will be reset as the last bit of each sync word enters the encoder.

The spacecraft will have an X-band transmitter, phase-coherent to the S-band transmitter, which will be present for radio science purposes only (i.e., no X-band telemetry will be possible). The X-band transmitter will have a power of 750 mW, while the S-band will have a power selectable of either 10 or 20 W using solid-state amplifiers instead of TWTs (traveling wave tube amplifiers). The despun high-gain antenna will have a gain of 25 dBi at S-band and 29 dBi at X-band. The despun sleeve dipole antenna will have a gain of 8 dBi, and the despun forward omnidirectional antenna and aft omnidirectional antenna will have a gain of slightly more than -6 dBi. The high-gain antenna is movable up to 17 deg in elevation, measured perpendicularly to the spin axis.

There will be many different telemetry formats as a function of mission phase; however, all format changes should be transparent to the DSN.

The frequencies assigned to the Orbiter Mission are Deep Space Channel 12 for the prime transponder, Deep Space Channel 11 for the redundant transponder, and Deep Space Channel 17 for the flight spare transponder. The actual frequencies are listed in Table 1 of Ref. 2.

The Command System will be using frequency shift keying/phase modulation where the two tones will be a Data 0 of 100 Hz and a Data 1 of 225 Hz. The command rate will be 4 bits/s, and individual commands will be 59 bits long. Contiguous commands after the first 59-bit command can be 48 bits long. There will be on the order of 370 different commands, the majority of which are redundant. The on-board command storage will have a redundant capacity of 128 locations in which can be stored either a specific instruction (command) or a delta time to be counted down until executing the next instruction. The redundant command storage units can be operated either in parallel for highly critical mission events or in series to effectively double the on-board capacity.

References

1. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *The Deep Space Progress Report 42-23*, pp. 37-40, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1974.
2. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *Deep Space Progress Report 42-27*, pp. 28-35, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1975.

Table 1. On-board experiments

Experiment	Principal investigator
Neutral particle mass spectrometer	H. B. O. Niemann Goddard Space Flight Center
Charged-particle mass spectrometer	H. A. Taylor, Jr. Goddard Space Flight Center
Electron temperature probe	L. H. Brace Goddard Space Flight Center
Retarding potential analyzer	W. C. Knudsen Lockheed Aircraft Corporation Palo Alto Research Laboratory
Ultraviolet spectrometer	A. I. Stewart University of Colorado
Infrared radiometer	F. W. Taylor Jet Propulsion Laboratory
Cloud photo-polarimeter	J. E. Hansen Goddard Institute for Space Studies
Magnetometer	C. T. Russell UCLA
Plasma analyzer	J. H. Wolfe Ames Research Center
Electric field detector	F. L. Scarf TRW
Surface radar mapper	G. H. Pettengill Massachusetts Institute of Technology
Gamma burst detector	W. D. Evans Los Alamos Scientific Laboratory

Table 2. Ground-based experiments

Earth-based radio experiments	Experimenter
Dual frequency radio occultation	A. J. Kliore/Jet Propulsion Laboratory and T. Croft/Stanford University
Atmospheric and solar corona turbulence	R. Woo/Jet Propulsion Laboratory
Drag measurements	G. N. Keating/NASA Langley Research Center
Internal density Distribution	R. J. Phillips/Jet Propulsion Laboratory
Celestial mechanics	I. I. Shapiro/Massachusetts Institute of Technology

Table 3. Pioneer Venus Orbiter—estimated DSN requirements

Network	Interval, h/day	Schedule (day number in orbit)	Purpose
26 m	4	1 to 120	Daily data and command sequence
	6	121 to 250+	Daily data and command sequence
	24	2 days out of 6 ^a	Navigation, mass properties
64 m	18	80 to 94 ^b 106 to 114 ^b	Cloud photopolarimeter polarimetry
	3	1 to 70	Short occultations
	6	150 to 165	Long occultations
	24	95 to 105 ^b 115 to 125 ^b	Cloud photopolarimeter imaging
	8	30 days between 40 to 110	Cloud photopolarimeter imaging
	3	1/wk ^c	Radar imaging

^a24 h/day every day preferred

^bExamples, subject to adjustment

^cAverage requirement, details unknown

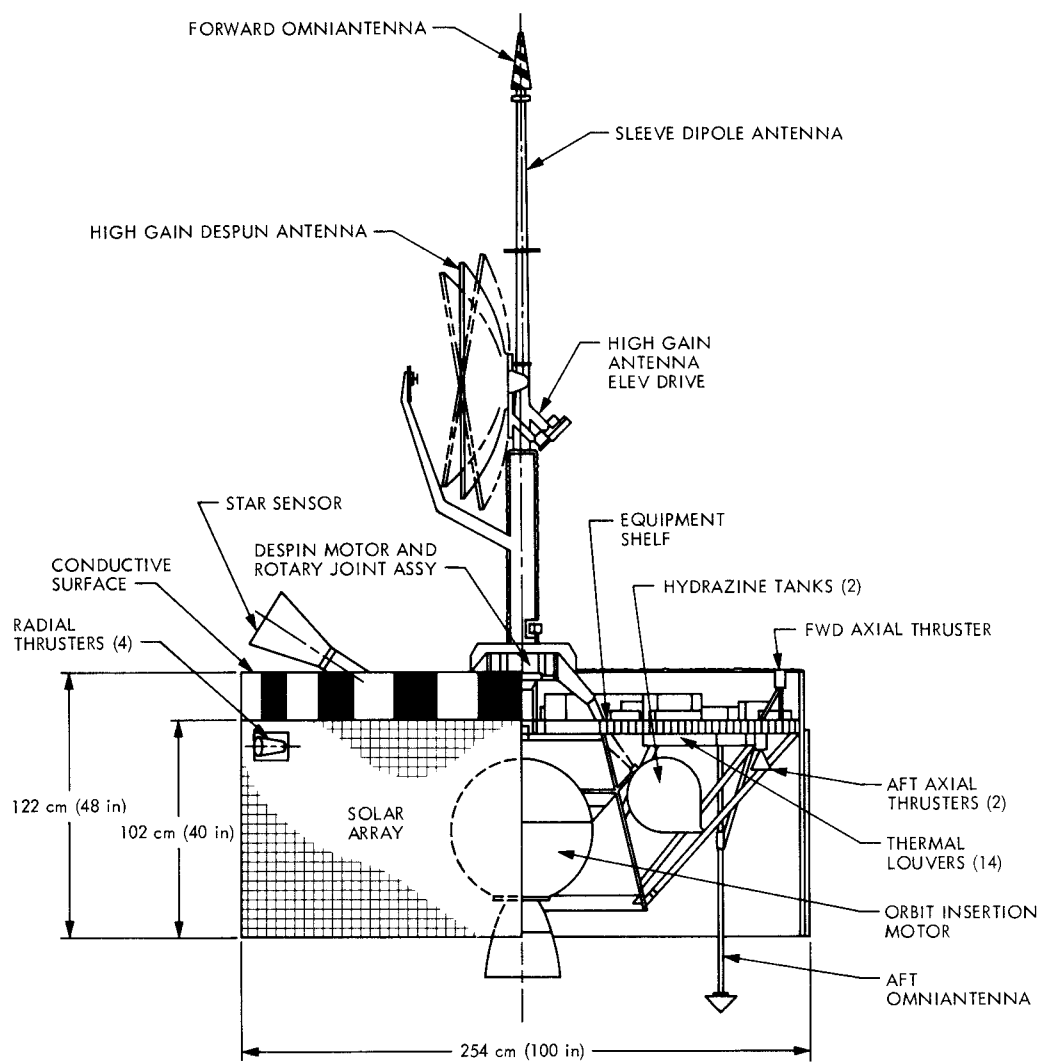


Fig. 1. Pioneer Venus 1978 Orbiter spacecraft

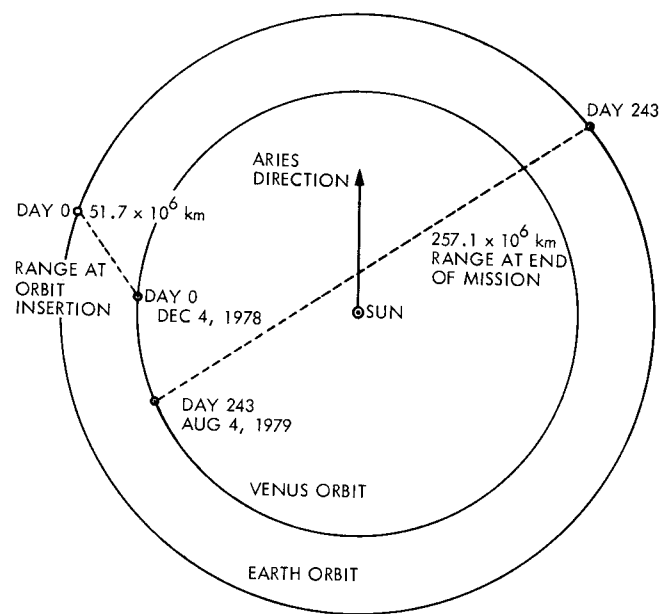


Fig. 2. Earth and Venus locations at start and end of Orbiter Mission

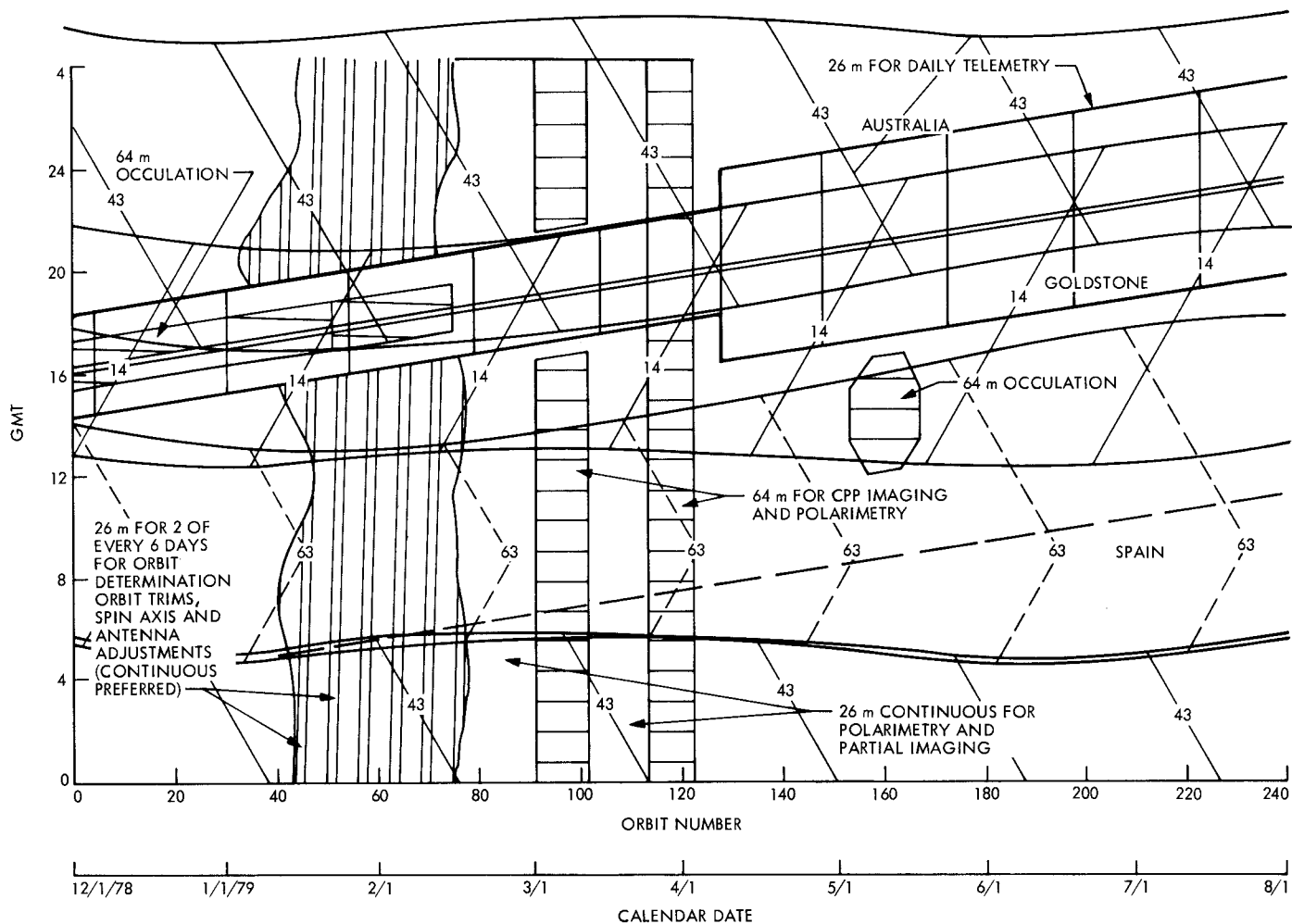


Fig. 3. DSN view periods for Pioneer Venus Orbiter and coverage requirements for suggested timing of periapsides

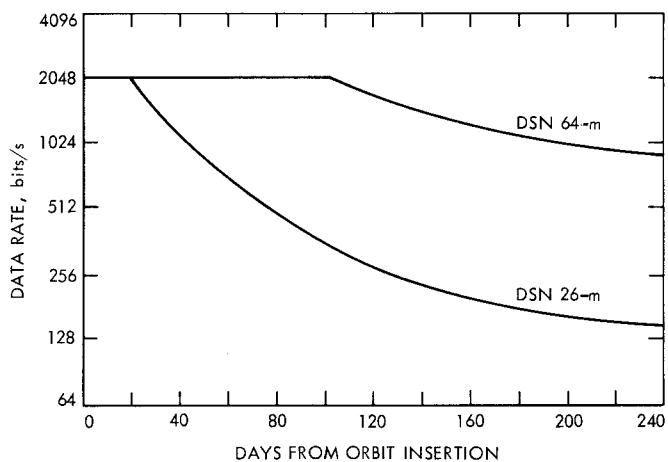


Fig. 4. Orbiter data rate capability, despun high-gain antenna high power mode